ARTICLE X.

NOTES ON CERTAIN MODES OF MEASURING MINUTE INTERVALS OF TIME.

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It has become necessary to devise means of estimating minute intervals of time for two purposes. Of these purposes, one is, to ascertain the absolute length of an interval merely, or the absolute duration of a transient phenomenon, such as the passing of an electric current over a given extent of wire. The phenomena to which contrivances for this end have been applied, are such as are observable by the sense of sight alone. The observation of the interval is necessarily independent of the observer's internal mechanism, or habit, or *personal equation* as it is termed; and it is not a matter of primary importance to settle, or posit in actual time, the beginning or the end of the phenomenon.

The other purpose in measuring minute intervals of time, is to determine the fraction of a second occurring between two phenomena, one of which is fixed in time, such as the beat of a clock, or the contact of its hand with a point, and the other is an incident occupying no assignable time, such as the contact of a star with a micrometer wire, or with the limb of the moon, &c. In this case the action of a single sense, or of more than one, may be put in requisition. There are two phenomena, each of which has to be posited in time; the interval between them, as to its length, depending on the relation of both to absolute time. The observation of the interval may or must be affected by the observer's mechanism of sense, or habit, or by his personal equation, in regard to both phenomena. The astronomer has therefore forms of mechanism of three very different orders to attend to. There is, first, his own internally; next that of his time-measurers; and lastly, that of the universe, which he aims at illustrating. The two former he has to study by comparison with the last, which alone affords him true position and dimension in time; while all his conclusions in regard to it, are dependent on his right use of the others. The in-

fluence of the first, or the special constitution of the observer, was, until lately, almost entirely overlooked. The improvement, however, of instrumental measures in these later times has brought it prominently forward, as one of the most influential elements affecting the accuracy of astronomical observations. Every thing, therefore, which can reduce the amount of uncertainty due to it, or which tends to eliminate altogether its effects, becomes of high importance.

To understand the limit to which uncertainty in observations may be diminished, in so far as it is dependent on personal equations, requires that we should analyze sensation and thought in their relation to time. Every one feels that both are conditioned to time; or that the changes of sensation and of thought do require a certain duration, so that, though rapid compared with many phenomena, they are slow compared with others. We must not confound the special differences in character, nor the physical distances in position, between the objects imaged by the presentative faculty of the mind, with the length of interval in time expended in the change. When our thoughts go from a line in the Odyssey to the ocean which it recalls, or from the diamond spark on a beetle's wing-case to the twinkling of the pole star, thought is not more rapid than in proceeding from the beetle's limb to his eye, or from one word to the adjoining one. The real velocity of thought consists in the number of changes which are possible in a given time. It does not follow from any thing known a priori as to a spiritual nature, that this velocity should be indefinite; or, in different orders of spiritual nature, should not follow different defining laws; except that in the highest or creative intelligence, thought must be timeless, absolute and without succession. It belongs to our connexion with material things, that thought should have a relation to them and to their movements, for these movements constitute and measure time to us. Whether changes of thought, or changes of sensation, be the more rapid, is an interesting question. The comparisons which it suggests, show plainly the fact, that thought is conditioned to time, and serve also, to some extent, to determine the condition.

An impression of light occurring oftener than ten (10) times in a second of time, will to most eyes appear a continuous illumination. Impulses of sound beyond (16) sixteen in a second, will not generally be apprehended as distinct sounds. In regard to neither sense do I, of course, speak at present of the physical vibrations which put our organs into a sentient state, but of the continuance of that state when it is produced in the sentient organ. It is the termination of this state which constitutes the change of sensation. The number of such changes in a given time is its velocity. We reckon therefore that the relative velocities in regard to sensations in the eye and the ear, are as 10 : 16. No ideas in the mind are perhaps simpler than those of number, in whatever mode, or under what-

ever form, they may, in different individuals, or at different times in the same individual, be presented to the intellect; and in no case is thought likely to be more rapid than in proceeding from number to number, so as to consider each individually, and not bring them together in groups or systems. Now if any one endeavours to put a series of them through the mind, under this restriction of their being separate and individual as mental conceptions, he will probably find that he cannot do so faster than his changes in sensation occur. He will find that, in regard to impulses of sound, he cannot number accurately those which the ear perceives to be distinct. If they amount, for instance, to 12 in the second, he will not, by the mind's effort only, ascertain confidently that such is the fact. If the impulses be reduced to 10 in the second, which would correspond with the limit of duration as to time in regard to the eye's sensations, counting of them with confident accuracy will be found to be difficult. It may be presumed that no one will, even with long continued trial and practice, be able to go beyond this. We may on the whole, therefore, conclude that while changes of sensation do not occur oftener, than at the rate of one in $\frac{1}{16}$ of a second, changes of thought, or of will, require about double the time of such perceptions. Thus there are insuperable limits to accuracy of observation, through means of the senses and the will alone.

Human physiology, therefore, comes here in contact with practical astronomy. In the observations of that science the circumstances of this kind which influence their accuracy may be complicated to a considerable degree. There may be acts of will, of judgment, and of sensation, all occupying time; and capable of variation in that respect in correspondence with training, habit, or constitutional peculiarities. Two observers watching the same phenomenon, such as the meridian passage of a star, will, though in circumstances which, in respect to the phenomenon itself, are identical, differ in their estimate of the time of its occurrence. This difference may originate from either or from both of two classes of incidents. There may be a difference in absolute time, in the completion of the contact to them individually, or in the sensation of the phenomenon; or there may be a difference in the accessary circumstances, by which the sensation of the phenomenon is referred to a known instant in time. It is probable that individuals differ in regard to both these classes of incidents; but that difference will be more conspicuous and important in regard to the second rather than the first. Differences in respect to the sensation of the phenomenon, though probably the less important, are more completely beyond control by any helps or modifications; and where such exist permanently, they will constitute the *proper* personal equations of individual observers, admitting of no modification but that of being, when ascertained, kept by training and habit, in a condition as uniform as possible in amount.

Art has more control over the accessary movements by which the phenomenon is referred to a known instant. In this class of incidents, either the same organs may be employed throughout the whole observation, or different organs may be called into exercise. The employment of one sense, or of the eye alone, has not been greatly practised, nor have the results been satisfactory. It was proposed by Breguet of Paris, about thirty years ago, to introduce a time-movement into the field of view of the telescope, to be studied simultaneously with following the course of the star. To this, Brewster objected, that when attention was concentrated on one object, the other would disappear from view. This would generally be the case, and to a person trained to other modes of observing, the difficulty might be perplexing. But if the habit had been acquired of watching the contact, and then instantly by an immediately subsequent effort, catching the indication of time, this would have required an interval, as all such operations must do, but all that would be needful for accuracy is, that personal training should render the interval constant, and that it be allowed for. It might in making an attempt to observe in this way, be found suitable that the time-movement were brought into the field of view by reflection only.

The more common modes of observation, call for the exercise of more than one organ. Of these modes the older employed seeing and hearing; the practice being to count seconds as beat on a clock, up to that immediately preceding the expected contact, and then to estimate the position in time of the phenomenon of contact between the beat last heard and the succeeding one. The estimate in this case might have been rendered dependent on the habit, reduced to regularity by training, of repeating in thought the numbers up to eight or to ten; and various modes of giving accuracy to the estimate might have been introduced. But the whole process will probably be everywhere superseded by the mode introduced and recommended by our American astronomers, by which these accessary movements are considerably simplified.

In this case we employ the eye to watch the phenomenon, and some other organ, such as the finger, to give a signal; the signal being a permanent mark by electric influence on some apparatus for time-movement, so that the instant of apprehended contact is registered on the apparatus. This improvement relieves the observer from all necessity of attending in thought to intervals of time. It leaves him free to watch for the single phenomenon of contact. Himself and the earth's rotation are now the only elements concerned in the proceeding. In the case of there being several parallel wires in the field of view, no process need interfere to direct his attention from the successive contacts.

If we bring under consideration now the condition of the observer, we shall find two circumstances remaining which will still give origin to differences of result in different individuals, constituting personal equations to be investigated and taken into account in re-

ductions. There is the sensation process of apprehending the fact of contact, and there is the complex process of will and of muscular effort, in giving the signal. All these three processes ought to be absolutely co-instantaneous. This, however, as we have seen, is impossible; for the three must be historically consecutive; and our only resource to secure accuracy must be to render the intervals of time regular in extent, and ascertained in quantity. The sensation process, or the apprehension, in the mind, of the contact or bisection will, in this case, differ somewhat in its circumstances from those which characterized it under former modes of observation. When the observer was counting the second-beats of a clock, he could retain mutually an apprehension of the space passed over by the star during the interval of the two consecutive beats, between which the contact or bisection happened, and of the relative size of the divisions before and after into which the wire, or the star in contact with it, divided that space; or, in counting minute portions of a second, he might both count onwards from the preceding beat to the contact, and thence onwards afresh to the subsequent one. In such ways he might get the phenomenon posited with some degree of accuracy between the two. In the more recent mode of proceeding, however, there can be no such resource. The instant of bisection must be the instant of signal. If the bisection passes over, the observation is lost, except a time-estimating process in the mind be employed to correct the instant marked on the time-movement apparatus, which it would be scarcely suitable to employ except in singular instances. The process of observation in general, with all probability, will be, that the observer "wills" the muscular movements which are to give the time signal of bisection, before the bisection is actually perfect, so as to allow for the interval which these movements need. It may be, that such almost unconscious anticipations of events, or mental movements of an analogous order, are mainly the cause of those differences in the results of observation, which may be termed *real* or proper personal equations as formerly alluded to.

Here a principle may be noticed, which is perhaps capable of being introduced with the effect of determining the relative perfectness of the bisections, at the instant when the will acts to give the signal. This consists, in the definiteness of the last impression on an organ of sense, when, for a time, no other is permitted to interfere with it. Attention to this circumstance explains some interesting phenomena. Nature provides examples of it in two modes. When we gaze at any rapidly moving stream or succession of bodies, the appearance to the eye, provided its axis of vision remain fixed, will be confused, or be merely a formless succession of uniform or slightly varying shades. It is known however that if such a stream, as, for example, if a shower of the drops of falling quick-silver in the dark be revealed by the quick and instantaneous flash of an electric spark, then will every mass in its proper shape appear to be suspended unmoved in the air. A similar effect is

produced when the eye is fixed on a swiftly revolving fly wheel, provided the axis of vision follow for an instant the ascent or descent of the rim. It will thus happen that the ends of the arms are seen momentarily with considerable distinctness, so as to give to the revolution an appearance of irregularity, which does not belong to it. In observing steadily the current of a river, there is a natural tendency in the axis of vision to follow bubbles, patches of foam, or other objects floating with the stream, against which it requires an effort constantly repeated, to replace the axis in the same direction. This adds to the variety and life-like motion of the stream. If attention be given to a cascade, with the axis of vision directed towards its summit, there is the same natural tendency to let it descend with the masses of falling water, which are thus revealed individually in their proper form and dimensions, all disappearing as the eye glances upward again. Hence there is an apparently capricious variation of appearance in these and some analogous instances, which never can be caught in painting, for all representations of them must correspond to their aspect when the eye-axis is absolutely fixed, or when the moving masses are not in its focus of vision. The effect is obviously traceable to the longer duration given to one impression in the eye, while its axis follows the movement, or to its relief from a succeeding impression coming on to interfere with one already received.

Another method of producing the same effect is by winking, or by rapid closing of the eyelid. The circumstances already mentioned as affecting the appearance of a waterfall, or other quick movements of masses in motion, are sometimes due to this influence. By thus preventing a subsequent impression from over-lapping and confusing one already received, an image before the mind is for a time stored up there, to be contemplated by it. If in marking the instant of bisection, by means of a signal given to a time-movement, it could be so arranged that the image in the state of bisection were instantly covered, then the examination of this last impression received from it, would decide as to the completeness of the bisection when the signal was given. This closing off of the image might be produced by the same finger-movement which sent the signal on to the time piece; or the eyelid and the finger might be trained to act in conjunction. Trial will readily show that different portions of the muscular frame act with sympathetic readiness under the same movement of the will.

As to the time-movement to which, in such a mode of proceeding, a signal is to be given, it seems to have been assumed that there is a necessity for a perfectly uniform motion, or one such that signals given after equal times were found to be separated by equal spaces on the dial-face, or on whatever surface may receive the mark of the signal. This uniformity is evidently by no means indispensable. It is enough that the movement take place under some known law, so that from the measurement or register of the spaces passed over by the

movement, the times may be deduced. Nothing offers itself so readily for this purpose as the motion of the pendulum of a time piece. The arc of movement corresponding to one second is sufficiently uniform in its amplitude, and is extensive enough to admit of being divided into spaces affording probably as minute and as correct measures of the fractions of a second as our physiological constitution will admit of our taking into account in practical operations. To render it available for this purpose, a metallic arc concentric with the arc of vibration is to be placed exactly under the pendulum, and resting on glass, so as to be in a state of electric insulation. A fine point in the axis of the pendulum vibrating above this metallic arc, will communicate or receive slight galvanic discharges, marking the period during the vibration at which, by means of the common apparatus recommended for such purposes, a galvanic contact is effected. If, between the metallic arc and the pendulum point, there be interposed a film or riband of paper chemically prepared to receive and retain a mark from the passing galvanic influence, the position of this mark will indicate the instant of the signal, measured from the beginning of the vibration. The paper may be ruled with parallel lines transverse to the movement of the vibrating point, so as either to mark equal subdivisions of the arc, from which the times may be deduced, or so as at once to present intervals corresponding to equal divisions of time. A time-movement of any character drawing this paper along, will secure the proper record of the signals made at the occurrence of the observed phenomena. It may be a subject of inquiry whether the galvanic influence passing between the metallic arc and the vibrating point, would not tend to disturb the rate of the clock. The same objection, if sustainable, will affect all time-movements on which signals are impressed by galvanic influence. The extent to which this tends to interfere with absolute accuracy, may be the subject of interesting experiment, if the case requires it. In the case of the pendulum it will be advisable to extend the metallic arc to some distance beyond the amplitude of the vibration. With this precaution to compensate for irregularity of force at the ends of the arc, if such should be apprehended, and having the electric tension of a low rate, it is not probable that its introduction, in giving a signal, would have any sensible effect in the rate of the clock. The effect, if capable of being recognised, would be estimated as a correction.

It may be worth inquiry, whether celestial phenomena may not, in certain cases, be made to give of themselves permanent signals of the time of this occurrence, so as to reduce such observations to mere linear measurements, or to coincidences with measures already made and marked. This would be accomplished if a star's pencil of rays could trace the star's path across the field of view in a permanent form upon a surface. Photography has reached such a condition as apparently to bring this within our power. The preparation composed of albumen, iodide of iron, alcohol and acetic acid, has been found

so sensible that it received a legible impression from a printed surface during the flash of an electric spark. This should give sensibility enough for the concentrated light of a star from a large object glass. By having, therefore, a surface of this kind moving with a defined velocity transversely to the direction of the star's path transiting the field of view, we should obtain the recorded signals, which we want. The requisite arrangements for such an effect, with reference to the eye piece and the transit wires, are sufficiently obvious. Determinate distances along the prepared sensitive surface in the direction of its motion would mark the times. The star's motion would be indicated by a dark line crossing this surface. If the transit wires were illuminated, they would appear on the surface as dark lines, parallel to the direction of its motion. The line of the star's motion would cross these obliquely, at an angle determined by the velocity of movement given to the surface. The effect of inflection at the edges of the transit wires, and of imperfection of focus in the instrument, might render these lines somewhat broad and indistinct as to their lateral boundaries; but points of coincidence in their axes would probably be determinable, with considerable precision. If the transit wires were not illuminated, they would then produce an interruption, or a difference of shade, in the line of the star's path, which might serve perhaps better to mark the instants of contact. A suitable degree of artistic skill may make lines on the prepared surface itself to become substitutes for the transit wires. With the employment of a good object glass alone, and with means of directing its line of collimation, in combination with arrangements of the sort now alluded to, it does not appear difficult to substitute the astronomical clock or chronometer, for the living observer, and to reduce almost indefinitely the causes of uncertainty in respect to siderial astronomy. To apply the same principle to the movements of the sun and moon would require some farther modifications, but most inquiries with regard to the movements of the planets and of conspicuous or solitary stars, would be facilitated and rendered more precise if these suggestions can be carried out.